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Nuclear Experimental Group I

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Research Activities

(Ⅰ)LIGHT ION NUCLEAR PHYSICS

a. Spectroscopic Study by Single Proton Transfer Reactions for ^{58,60,64}Ni (T.Tohei,T.Nakagawa,A.Terakawa,A.Narita,T.Inomata,T.Matsumoto,H.Orihara,K.Ishii,M.Hosaka,S.Miyamoto,Z.Guan,Y.Ishimaru,K.Miura and H.Ohnuma)

Single proton transfered states have been observed in the ^{58,60,64}Ni (d,n) reactions by using 25MeV deuterons from the CYRIC AVF cyclotron and a TOF facility. Systematic results for the occupation probabilities of the shell model orbits in the ground states and single particle energies have been deduced from observed spectroscopic factors.

b. Systematic Occupation Probability Study for sd shell nuclei through (d,n)Reactions (T.Tohei,T.Nakagawa,A.Terakawa,A.Narita,T.Inomata,T.Matsumoto,H.Orihara,K.Ishii,M.Hosaka,S.Miyamoto,Z.Guan,Y.Ishimaru,K.Miura and H,Ohnuma)

Spectroscopic factors obtained in the (d,n) reactions on sd shell nuclei were compared with the results of the recent shell model calculation in the basis of the complete 2s1d shell model space. Systematic occupation probabilities for proton orbits in the ground states were deduced in this mass region.

c. A Study of Two Proton Transfer Reactions on ^{40,42,44}Ca (T.Tohei,T.Nakagawa,A.Terakawa,A.Narita,T.Inomata,T.Matsumoto,H.Orihara,K.Ishii,M.Hosaka,S.Miyamoto,Z.Guan,Y.Is-

himaru,K.Abe,T.Suehiro,K.Miura and H.Ohnuma)

Mearurements for the (^{3}He,n) reactions on ^{40,42,44}Ca at 50MeV were done by using a ^{3}He beam from the CYRIC AVF cyclotron and a TOF facility to observe higher J members of the multiplets for two proton configurations. Differential cross sections have been analyzed with an exact finite range DWBA code TWOFNR which contain one-and two-step processes.

d. **Nuclear Bremsstrahlung** (M.Hosaka,K.Ishii,S.Miyamoto,Z.Guan,Y.Ishimaru and H.Orihara)

The study of nuclear bremsstrahlung has been performed by the measurement of high energy γ-rays produced in the (h,h',γ) reactions at Eh= 65 MeV on ^{9}Be,^{12}C,^{27}Al,^{48}Ti, ^{64}Zn,and ^{208}Pb. We have observed quanta with the high energy of $\sim$65 MeV. It is considered that these high energy photons are emitted by the whole of the ^{3}He nucleus.

(Ⅱ)PHOTOREACTION

a. **Coinidence Experiments of (e,e'n) on ^{12}C and ^{16}O** (T.Saito,K.Takahisa,M.Oikawa,Y.Suga,T.Tohei,T.Nakagawa,K.Abe and H.Ueno)

(e,e'n)events on- and off- plane for ^{12}C and on- plane for ^{16}O have been measured in the giant resonance energy regions by using continuous electron beam of 130MeV from SSTR at Laboratory of Nuclear Science,Tohoku University. An information about the strengths of the longitudinal and transverse interference terms in the giant resonance region has been obtained from the out of plane measurement for ^{12}C.

b. **Proton Number Dependence of Charged Pion Photoproduction** (T.Yamaya,H.Ishigaki,K.Shoda,H.Tsubota,T.Hotta and T.Tamae)

Charged Photopion energy spectra from ^{1}H, ^{9}Be and ^{12}C were measured with a large solid angle magnetic spectrograph for pions momentum analysis.

e. **Soft Giant Dipole Resonances of ^{9}Be** (T.Yamaya,H.Ishigaki,K.Shoda,H.Tsubota,T.Hotta and T.Tamae)

The E1 strengths of the charge exchange dipole resonances by the (γ,π^{+}) reaction were in agreement with the results of the theoretical calculations assuming the one neutron halo contibution in ^{11}Be.

(Ⅲ) NUCLEAR PHYSICS BY CHARGE-EXCHANGE (p,n) REACTION

(H.Orihara,M.Hosaka,S.Miyamoto,Z.Guan,G.C.Jon,A.Terakawa,K.Ishii,A.Narita,T.Nakagawa, K.Miura and H.Ohnuma)

In the course of exploration by the charge-exchange (p,n) reaction for spin-isospin modes of nuclear excitation, and their relation to the π- and ρ-meson exchange interactions, we have studied;

(1) effective N-N interaction in low-energy

(2) test of the (0s0p1s0d) full-space shell model, investigation of Gamow Teller(GT) strength distribution in sd-shell nuclei
(3) search for the GT-strength distribution in the $f_{7/2}$-shell nuclei
(4) sampling of isovector spin-excitations other than the GT-transition

Study of the nuclear mean field by nucleon-nucleus scattering has been carried out including neutron scattering experiment from N = Z nuclei. Another newly developed work is concerning detection of high energy γ rays in several tens MeV region emitted through charged particle bombardment on nuclei.

a. Spin-isospin excitation in the ^{42,44}Ca (p,n) ^{42,44}Sc reaction

We have performed systematic studies of the (p,n) reactions at E_p = 35MeV for fshell nuclei. For f-shell nuclei, the shell model wave functions, by which one can obtain transition density needed for evaluation of the theoretical cross section,is available by recent work by Brown and his collaborators. Differential cross sections for the ^{42,44}Ca (p,n) ^{42,44}Sc reactions were measured at E_p = 35MeV. A number of spin-isospin excitations have been observed including Gamow-Teller type $\triangle J^\pi = 1^+ \triangle J^\pi = 2^-$ transitions. Distorted-wave Born-approximation (DWBA) calculations using shell model wave functions have successfully reproduced the experimental results.

b. Gamow-Teller strength distribution for low-lying states in A $\sim$ 110 nuclei studied by (p,n) reaction.

Low-lying states in A = 100 through 120 nuclei have their J^π of 1^+. Gamow-Teller strengths for beta-decay between these nuclei have so far been measured. However, in some cases, where the life time of the parent state is too short, log ft values have not been determined. It has been almost established that (p,n) cross sections are proportional to the corresponding β-decay strengths. (p,n) cross sections on ^{108}Pd, ^{110,112,114,116}Cd, and ^{116,118,120}Sn have been measured at 35MeV. Proportionality between (p,n) cross sections and known β-decay ft-value has been tested successfully.

A number of new GT-strengths have been proposed.

c. (d,^{2}He) reaction at E_d = 260MeV as a possible probe to nuclear spin-isospin excitation

The (d,^{2}He) cross sections were measured at E_d = 260MeV for light nuclei at small angles including 0° with a large solid angle, wide momentum-acceptance spectrometer system. Observed excitation-energy spectra show remarkable similarity to those for (p,n) at similar incident energy per nucleon. This, along with angular dependence of the cross section and preliminary DWBA calculation, indicates the direct nature of the reaction and selective excitation of the DS = 1 components in the (d,^{2}He) reactions at this energy. The measured 0° cross section shows a strong correlation with the known beta-decay strengths,making (d,^{2}He) reactions an attractive probe to the study of spin-isospin excitation modes of nuclei.

d. Elastic and Inelastic nucleon scattering on N=Z nuclei in E ≦ 35MeV and core-polarization effect derived from a dispersive optecal-model analysis

Elastic and inelastic, leading to the 2^+ state in ^{12}C and ^{28}Si, neutron scattering on ^{28}Si were measured at E_n=35MeV. By analyzing neutron data at E_n = 14.8, 16.9, 20.0, 21.7, 26.0 in addition to those at 35.0MeV with the optical model, energy dependence of the parameters has been obtained. Also analyzed are proton scattering data in 18.7 ≦ Ep ≦ 40.2MeV. Alarger imaginary volume depth of 9.05MeV has been obtained at E_n=35MeV. By developing a despersion relation approach, the real part of the higher-order (core-polarization) term was estimated separately from the Hatree-Fock term. The Coulomb corrected $(J_n-J_p)/A$ values seem to be interpreted by core polarization correction for neutron and proton mean fields.

(IV)INTERMEDIATE ENERGY PHYSICS

a. Study of the $\eta\pi$-System in the π-p Reaction at 6.3GeV/C (T.Tsuru, T.Nakagawa, T.Matsumoto, et al., KEK-PS E179 Collaboration)

A study of the $\eta\pi^-$ system has been done in the reaction $\pi^-p\rightarrow\eta\pi^-p$ at 6.3GeV/C. An enhancement with a large forward-backward asymmetry of the P_+ wave has been observed around 1.3GeV/C^2 in the Gottfried-Jackson frame of the $\eta\pi^-$system.

b. Search for the S=-2, $IJ^P=00^+$ State through the $pp\rightarrow k^+k^+X$ Reaction (H.Kawai, T.Nakagawa et al., KEK-PS E248 collaboration)

An experiment has been preparing to observe the S=-2, $IJ^P=00^+$ six quark state by using the $pp\rightarrow k^+k^+\ \Lambda\Lambda, \Lambda\Lambda\rightarrow$ H channel. Primary protons of 13GeV/C from KEK-PS and asymmetrically installed double arm spectrometers will be used for the measurement.

(V)HEVY ION PHYSICS

a. Alpha-cluster Structure in the fp-shell Nuclei (T.Yamaya, H.Ishiyama, M.Fujiwara, S.Kato, T.Suehiro, K.Katori, T.Itahashi and S.Ohkubo)

The rotational $K^\pi=0^+$ and 0^- bands as the parity-doublet bands in ^{40}Ca and ^{44}Ti were observed for the first time in the fp-shell nuclei.

b. Higher nodal α-cluster band in ^{40}Ca (T.Yamaya, H.Ishiyama, M.Fujiwara, S.Kato, T.Suehiro, K.Katori, T.Itahashi and S.Ohkubo)

The strongly excited members of the higher nodal α-cluster rotational band were found at the excitation energies above 11MeV in ^{40}Ca via the (^6Li,d) reaction.

c. Forward Nuclear Glory in $^{15}N+^{28}Si$ Scattering (T.Yamaya, H.Ishiyama, K.Suzuki, K.Kotajima, T.Sinozuka and M.Fujioka)

An existence of the forward nuclear glory in heavy-ion scattering was observed in

the $^{15}N+^{28}Si$ system at E=85MeV. As the results, the total reaction cross section, the nuclear scattering amplitude at 0°, and the depth of the imaginary potential term of the optecal model potential were obtiained.

d. **Low-Energy Radioactive Beams by Inversion Kinematics** (T.Yamaya,H.Ishiyama,K.Suzuki, K.Kotajima,T.Sinozuka and M.Fujioka)

Kinematically focussed radioactive beams of energies lower than 10MeV/nucleon were produced by means of inversion kinematics in heavy ion induced charge exchange reaction on ^{1}H.

e. **Focused Mono-Energy Neutron Source by a Heavy Ion Collision** (T.Yamaya,H.Ishiyama, K.Suzuki,K.Kotajima,T.Sinozuka and M.Fujioka)

Focused and mono-energy neutron beam at En = 4MeV was produced at 0° via the reaction (13C,n) on ^{1}H. However a development of H^{2} target is still more indispensable.

(VI)ION-ATOM COLLISIONS AND PIXE

a. **Inner Shell Ionization** (K.Ishii,H.Orihara,K.Sera,J.Iihara and S.Morita)

Multiple inner shell ionization mechanism, atomic alignment effect induced by ionizations and chemical effects in X-ray spectra are studied by the measurement of characteristic X-rays with a high resolution crystal spectrometer.

b. **Study of Ion-Atomic Collisions by the Use of a High Resolution Magnetic Spectrometer** (K.Ishii,H.Orihara,I.Katayama,A.Ando,Y.Haruyama,and H.Ogawa)

Measurement of momentum distribution of scattered particles ionizing K shell electrons have been successfully achieved by the use of the high resolution magnetic spectrometer RCNP (RAIDEN).

c. **Continuum X Rays Emitted from an United Atom** (K.Ishii,K.Maeda,Y.Sasa,M.Uda,J.Kawai, and S.Morita)

Continuum X rays produced by the bombardments of Bi-ions for targets of C~Bi are studied by using the RIKEN HILAC. Bremsstrahlung produced by the united atom (United-atomic bremsstrahlung) is experimentally and theoretically investigated.

d. **PIXE** (K.Ishii,H.Orihara,H.Ohashi and S.Yumoto)

Using PIXE analysis, we have investigated a concentration of Al in a brain tissue of rat for research of Alzheimer's disease.

e. **Density effect in relativistic ionzation,** (D.W.Spooner,W.E.Meyerhof,J.J.Kuffner, E.C.Montenegro,K.Ishii,S.E.Kuhn,S.M.Kawall,D.G.Jensen and Z.E.Meziani)

The density effect predicted by Fermi has been studied by the use of 22.6GeV electron beam of SLAC. We have observed this effect in the X ray yields produced at the

front of Al and Cu targets.

(VII) INSTRUMENTS

a. Performance test of a BaF_2 detector system for high-energy γ-ray (H.Orihara,M.Hosaka,S.Miyamoto,Z.Guan,G.C.Jon,A.Terakawa,K.Ishii,A.Narita,T.Nakagawa,K.Miura and H.Ohnuma)

We have constructed a high-energy γ-ray measurement system composed of twelve pieces of BaF_2 and plastic scintillators. The detector assembly is placed in 90° direction with respect to the incident beam and 15 cm from the target. A lead collimator is placed between the detector and the semicircular target-chamber, in order to obtain a good detector response by collimating high-energy γ rays onto the central BaF_2 scintillator. Unexpected γ-rays are rejected by the time-of-flight (TOF) analysis, and major events due to neutrons are rejected by TOF, together with the pulse-shape analysis. In addition to performance tests for this system, further improvements to measure high-energy γ-ray from the (n, γ) reaction has been carried out.

b. Positron-CT and SQUID (K.Ishii,H.Orihara,and S.Watanuki)

Technical development has been performed for Positron Emission Tomograph. A system of SQUID (Superconducting quantum interference devices) has been developed for the brain research, especially the study of rapid response functions.

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9. Low-Energy Radioactive Beams by Inversion Kinematics, T.Yamaya,M.Saito,T.Miyamoto, T.Ishigaki,K.Kotajima,K.Gotoh,T.Shinozaki and M.Fujioka,Nucl.Inst.and Meth.in Phys.Res. B70(1992)374

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14. X ray Production,Inner Shell Ionization and Reading's Theorem in Ion-Atom Collisions, K.Ishii,Int.Jour.of PIXE 2 (1992)197.

15. Aluminium Neurotoxicity in the Rat Brain, S.Yumoto,H.Ohashi,H.Nagai,S.Kakimi,Y.Ogawa,Y.Iwata and K.Ishii,Int.Jour.of PIXE 2 (1992)493

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Doctor Theses(March 1993)

D1) Precision Determination of the Hyperfine Constant of $^{87}Sr^{+}$ using an ion-trap and a laser-microwave double resenance method, Hitoshi Sunaoshi

D2) Proton shell structure of the 2sld shell,Ca,Ni and Pb nuclei studied with the (d,n) riaction, Atsuki Terakawa

Master Theses(March 1993)

M1) The (p,n) Reaction on Cd and Sn Isotopes, Zhong Guan

M2) Forward Nuclear Glory in $^{15}N+^{28}Si$ Scattering, Takeshi Ishigaki

M3) Spectroscopic Study for Single Proton States in $^{59,61}Cu$ through (d,n) Reaction, Toru Inomata

M4) Development of a Surface Ionization Ion Source for on- and off-line Mass Separation, Masaaki Furukawa

M5) Elastic and Inelastic Nucleon Scattering on ^{12}C at En=30,35MeV, Syouichi Miyamoto